An Articulated Skeletal Analogy

of the Human Upper-Limb

Graham Paul Whiteley

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Contents

ABSTRACT

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Currently available upper-limb prostheses do not meet the needs or aspirations of the amputee.

Many technical challenges have been given as the limiting factors on the further development of these prostheses. Generally developments have occurred as incremental developments on three existing moderately successful archetypes; the cosmetic, body-powered and myoelectric prostheses.

Continued development on these archetypes appears to be further separating prostheses into those primarily considered cosmetic and those primarily considered functional. However, amputees have a need both for function and cosmesis from their prostheses.

Technology currently being developed for actuation and control in other laboratories indicates that the previous limitations placed on prosthesis design may be challenged. Therefore, it is appropriate to look for new design archetypes.

This thesis describes the development, implementation and evaluation of mechanical analogies of the skeletal components of the human hand and arm which have the potential to inform the design of a new generation of upper-limb prostheses integrating cosmesis and function in a single device.

The research has been undertaken using a form of practice led design research methodology. This iterative methodology uses physical models for both evaluation and also as a means of encouraging end-user involvement in the design process. These evaluations are then used in subsequent cycles of research activity.

The research has concentrated on developing mechanical analogies of the joints of the hand, wrist, forearm and elbow. The joints of the hand are shown to have a simple and similar structure. Therefore, a modular mechanical archetype has been elucidated that results in a hand configuration made from multiple similar modules positioned at different points throughout the hand. However, the wrist and forearm contain more complex joints which have been found to be unique to their anatomical position. The selection of appropriate prototyping techniques has been an integral part of the research.

Problems have arisen in assessing the degree of analogy achieved because the intact joints of the human skeleton are covered by soft tissue that has not been part of the skeletal analogy implemented. Additionally, it is postulated that there are subtleties to human movement which are not reflected in standard anthropometric measures. Therefore, a two stage evaluation has been undertaken that assesses the quality of the analogy realised in the models. This consists of goniometric measures to quantify basic angular rotations whilst qualitative evaluations by professionals with a good anatomical knowledge have been used to assess the more subtle movements within the joints.

The skeletal mechanical analogy developed through this research has been shown through evaluation to simulate the articulations of the human upper-limb. The model embodies design principles that appear to have short and long term significance to the field of prosthetics. The production of a tangible model has not only aided evaluation but has also stimulated research in other centres into ways of actuating and controlling a future upper-limb prosthesis. Additionally, the mechanical analogy may have applications in the field of tele-presence robotics, aerospace and the entertainment industry.

Plan of thesis

This research was carried out largely through practical design work and the form of the thesis reflects this. Drawings and artefacts are an integral part of the material presented, and in some cases these provide the clearest means of communicating aspects of the research.

The process used in the preparation of this thesis began with the creation of a systematic archive of models and drawings created during the project. Once assembled this archive was catalogued. The work is described by a series of images extracted from this archive accompanied by narrative text. The full catalogue of material is given in appendix (iv).

The work described in this thesis falls naturally into two parts: the development of a model hand and its evaluation; and the development of a model arm and its evaluation. For convenience and to aid understanding the work in each section has been divided into chapters, each of which addresses a particular joint or joint area.

The chapters are arranged as far as possible in the order in which the work was carried out. However, the research was essentially iterative and where developments were carried out in parallel this is indicated in the text.

A system of annotation has been devised for images and this is described in full on the following page.

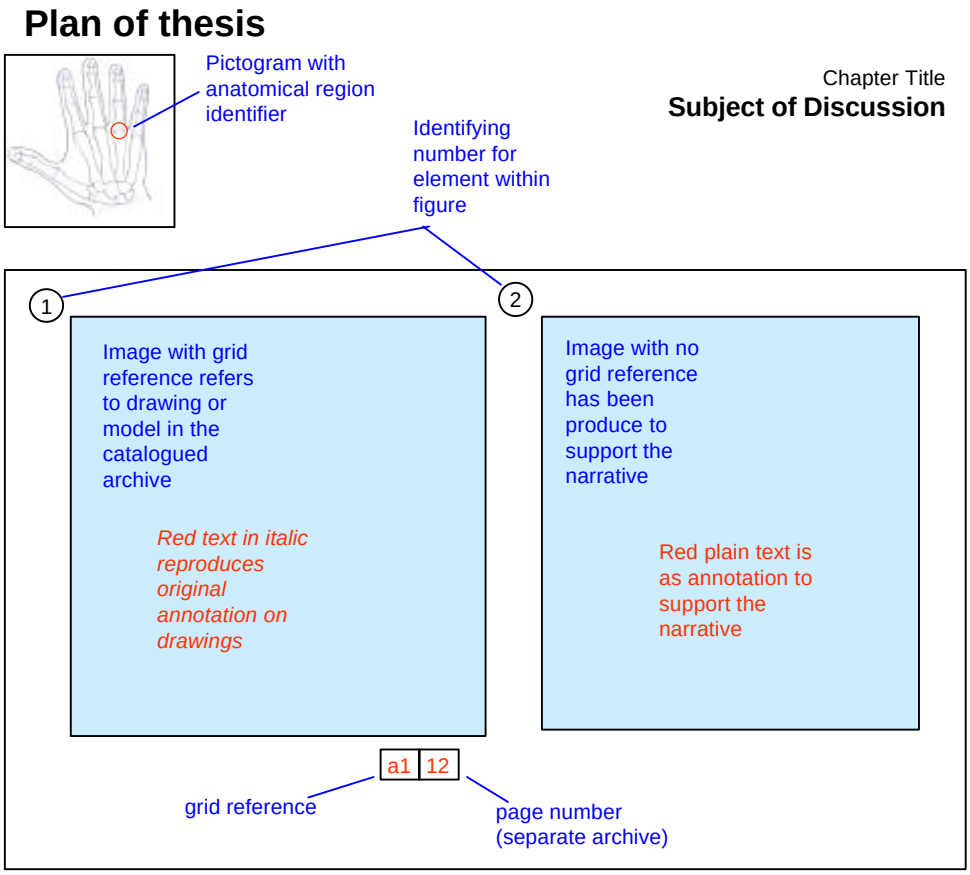

Fig x.y Annotation of figures

The page layout of the main body of original work of the thesis is laid out with figures from the development work serving to explain points made in the text. Where sketches or sub-diagrams are referred to in the text it is done thus (1).

This format has not been followed in both the methods and conclusions chapters.

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Dedication

For Mum